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# RESEARCH ON THE INFLUENCE OF MINERS' ENERGY EXPENDITURE ON COAL MINING EFFICIENCY

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# ДОСЛІДЖЕННЯ ВПЛИВУ ВИТРАТ ЕНЕРГІЇ ГІРНИКІВ НА ЕФЕКТИВНІСТЬ ВИДОБУТКУ ВУГІЛЛЯ

**Purpose.** To establish regularities of influence of miners' energy expenditure on coal mining efficiency.

**Methodology.** Methods of mathematical modeling, mathematical analysis, reliability theory, biomechanical methods, mining, full-time and visual observations with the use of modern information systems, devices and computer systems were used.

**Findings.** The regularities of change of miners' energy expenditure depending on the cutter-loader feed rate in the stope are established. The optimal speed of a miner's movement along the longwall face is determined by the criterion of energy expenditure per a meter of distance passed at different seam power. To assess the comfort of working conditions, it is proposed to use the factor of a miner's energy expenditure per ton of coal mined. It is established that the economy of a machinist's movement is inversely related to the energy consumptions per ton of coal mined, increases linearly with increase in the cutter-loader width and in quadratic dependence with increase in the cutter-loader feed rate. The efficiency of coal mining is determined by the economy of the miner's actions and the power consumptions of the cutter-loader, with increase in the cutter-loader feed rate the efficiency approaches the limit determined by the energy expenditure of miners. The regularities of change in the efficiency coefficient of miners are established when working with and without a respirator, depending on their age and qualifications; it was found that when working with a respirator, the productivity in the case of an experienced worker increases, whereas in the case of a young worker, productivity decreases.

**Originality.** The regularities of coal mining efficiency relation to miners' energy expenditure, the speed feed rate and the width of the cutter-loader have been established for the first time, and limits on the longwall face productivity are determined.

**Practical value.** A methodology has been developed for research on the energy expenditure of miners to determine the efficiency of coal mining and the professionalism of miners.

**Keywords:** *miners, energy expenditure, stope, coal mining efficiency*

**Introduction.** In recent years, the technology of underground coal mining remains constant, while stoping complex are being improved, their power capacity and productivity are increasing. Miners need to ensure the design characteristics of mining equipment. This issue is most acute for high-productivity longwall face equipped with the latest technology. Therefore, it is important to take into account the energy expenditure of miners moving along the longwall face during the design of winning equipment.

**Analysis of recent research and publications.** One of the parameters that characterize the energy expenditure of miners in the coal mining process is their biomechanical characteristics. Developers of modern winning technique and technology, even at the design stage, should be given tasks to take into account the individual characteristics of miners and to estimate the influence of miners' energy expenditure on the efficiency and safety of mining processes, and to resolve the questions of training and selecting personnel that is capable of managing of modern mining machines and complexes effectively.

Modern safety problems and the function of man in the event of accidents are discussed in [1–4]. In [1], the methodology of developing a warning index system for coal mine safety based on collaborative management is resulted. In [2], the connection between severe injuries and accidents in coal mines is considered. In [3], the results of experimental studies of physiological changes of people trapped in coal mines accident are presented. In [4], research was carried out on the trends of coal mine accidents and on the characteristics of human factors.

Continuous improvement of respiratory protection also requires additional studies of miners' energy expenditure during coal mining. So, in [5] the stress, arising at long wearing of respirators, is considered. In [6], the factors affecting filter penetration and quality factor of particulate respirators are analyzed. In [7], a new algorithm for determining the respiratory contact area was proposed. In [8], the results of comparative studies of the protective effectiveness of filter respirators are presented.

**Unsolved aspects of the problem.** The establishment of regularities in the energy expenditure of miners in the stopes and their influence on the efficiency of coal mining is an actual scientific and applied problem, which is important for increasing the productivity level, safety and labor protection in coal mines.

**Objectives of article** are to carry out research and to establish regularities of influence of energy expenditure of miners on coal mining efficiency.

**Presentation of the main research.** Typical positions of miners in the process of moving along the longwall face and controlling the mining machine at different seam power (*m*) are: at *m* up to 0.8 m the miner-machinist usually moves behind the cutter-loader along the longwall face in the prone position (crawling), at *m* from 0.8 to 1.3 m, the most convenient way of moving is to move on the knees (on all fours), at power of 1.3 to 1.7 m the machinist moves in a crouch position and only at *m* over 1.7 m the machinist moves in the usual position for the man – full-length.

When equipping longwall faces with complexes of a new technical level (NTL) and high reliability of coal mining, the movement speed of miners can impose limitations on the design productivity of cutter-loaders. To implement the project characteristics of NTL complexes, a condition $v \geq v_f$ must be ensured, i.e. the movement speed of a miner $v$ should be equal to the cutter-loader feed rate $v_f$.

The movement speed of a person is directly proportional to the length and frequency of steps

$$v = l \cdot n,$$

where $l$ is the length of the step, m; $n$ is the frequency of steps (movement rate), 1/min.

When the machinist moves crawling or on his knees (on fours), the temp is determined as the number of cycles per minute, and the length of the step is equal to the distance passed in one cycle (step).

Increasing the cutter-loaders feed rate and, correspondingly, the movement speed of the miner along the longwall face requires the miners to increase energy expenditure. From the point of view of biomechanics, the total energy expenditure of a person is the metabolic energy consumptions on movement. In turn, the metabolic energy is formed by thermal energy losses and total mechanical energy. The latter consists of the work of internal organs and obvious mechanical work (external and internal). The latter refers to the work performed when moving parts of the body are relative to the gravity center. External work is the work in the longitudinal and transverse direction. Thus, when a miner is moving through the longwall face, only work in the longitudinal direction is useful. Other energy expenditures are not useful in relation to the criterion of productivity - the miner's movement in the longwall face, but are an integral part of his movement.

The change in energy consumptions $E$, W due to the movement speed is expressed by the following known formula

$$E = E_0 + b_1 v + b_2 v^2, \quad (1)$$

where $v$ is the speed of movement, m/min; $E_0$ is the energy expenditure when motionless, $W$ (when estimating energy consumptions by heart rate $E_0 = HR_0$, where $HR_0$ is the heart rate when motionless, bpm); $b_1$, $b_2$ are empirical coefficients characterizing the body's reaction to the load. Parameters change in the ranges of $E_0 = 230–280$ W; $b_1 = 0.15–6$; $b_2 = 0.05–2$. Their minimum values can be taken to carry out engineering calculations.

Dependence of energy expenditure on the movement speed of the miner along the longwall face for domestic traditionally used complexes and NTL complexes is shown in Fig. 1.

The graphs in Fig. 1 show that in mines with a high load, with full implementation of the technical capabilities of modern NTL complexes, miners will carry greater energy expenditure than when working with traditional complexes. Thus, increasing the productivity and feed rate of the cutter-loader will increase miners' energy expenditure in the process of movement along the longwall face and the operating of the cutter-loader.

In addition to energy expenditure, another important criterion for the effectiveness of human movements is mechanical productivity. An important biomechanical criterion, characterizing the effectiveness of motor actions in moving, is the energy expenditure per unit of distance.

Dividing the parts of equation (1) by the speed $v$, we obtain the dependence of the change in energy expenditure per unit of distance on the movement speed of the miner along the longwall face

$$\frac{E}{v} = \frac{E_0}{v} + b_1 + b_2 v. \quad (2)$$

Differentiating the right-hand side of expression (2) to $dv$, we obtain: $\frac{E}{v} = b_2 - \frac{E_0}{v^2}$. This equation indicates the existence of the minimum type extremum of the function (2) at the optimum movement speed, which provides the minimum energy expenditure per unit of distance.

Fig. 2 shows the dependence of energy expenditure per unit of distance with a change in the movement

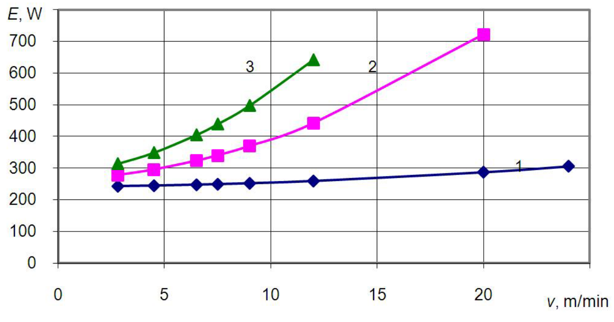


*Fig. 1. Dependence of energy expenditure of a miner on the movement speed along the longwall face:*

*1 – at m >1.7 m; 2 – at m = 0.81...1.3 m; 3 – at m = = 0.7...0.8 m*

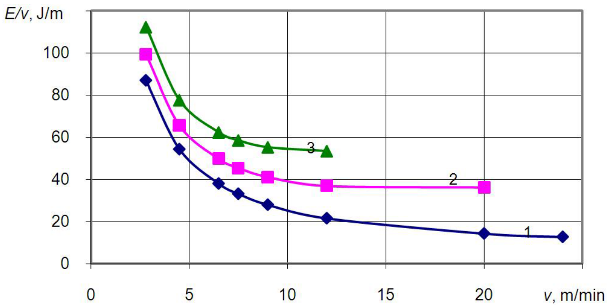


*Fig. 2. Dependence of energy expenditure on the movement speed of a miner along the longwall face:*

*1 – at m > 1.7 m; 2 – at m = 0.81...1.3 m; 3 – at m = = 0.7...0.8 m*

speed of the miner along the longwall face. The analysis of the graphs shows that for the speed range typical for traditional complexes and NTL complexes, the energy expenditure per unit of distance, in distinct to the total energy expenditure, is reduced. Solving the equation $\frac{E}{v}=b_2-\frac{E_0}{v^2}=0,$ we obtain the optimal (for a person with average statistical parameters and under optimal environmental conditions in the workplace) speed of the miner's movement along the longwall face, which at crawling along the longwall face is equal to 12 m/min; when moving on all fours is 16 m/min; in the usual position it is 50 m/min. Accordingly, for modern cutter-loaders, the optimal speed (by the criterion of energy expenditure per unit of distance) has not been achieved yet.

Dependence (1) is quadratic and suggests that movement with the same speed is less energy-intensive than moving at a variable speed with the same average speed, which is due to the dominance of the kinetic energy fraction in the total energy of the miner's movement and the irregular character of its expenditure when the speed variation. Thus, for longewall faces with a high load, with high reliability of the coal mining process, it is necessary to ensure a constant cutter-loader feed rate $v_f =$ = const, which will result in economy the miner energy expenditure.

In alternating cyclic movements, which include all types of the miner's movements on the stope during coal mining, the energy expenditure per meter of distance passed (2) is also used to characterize the economy. An important criterion of optimality in coal mining is the economy of the miner's movement, which is inversely proportional to the energy expenditure per unit of work performed or the unit of distance passed, and the most important rule of the miners' work is the principle of minimum energy expenditure. When the machinist is moving along the longwall face the useful work is to move in the longitudinal direction. The economy of a miner is inversely proportional to the energy expenditure per unit of distance

$$CE=\frac{1}{\frac{E}{v}}=\frac{1}{\frac{E_0}{v}+b_1+b_2v}. \quad (3)$$

Formula (3) reflects the efficiency of the machinist of a cutter-loader in terms of his biomechanical characteristics and indicates an increase in the profitability of the miner with an increase in the cutter-loader feed rate. Economy reaches an extreme value at the optimum movement speed and the minimum energy expenditure per meter of distance. The above calculations indicate that ceteris paribus an extreme value will be achieved at crawling along the longwall face $v_{opt}$ ≈ 0.7 km/h ≈ ≈ 12 m/min; on knees – $v_{opt}$ ≈ 0.97 km/h ≈ 16 m/min; in the usual position $v_{opt}$ ≈ 3 km/h ≈ 50 m/min.

Normalizing the exponent (3) relative to the optimum movement speed, we have the dependence of the economy of the miner on the speed of movement along the longwall face (Fig. 3).

Thus, for miners with low movement speed along the longwall face with lower ranges of extractable seam power, the rule of minimum energy expenditure is violated.

The quantity of coal mining from a meter of longwall face can be determined by the formula

$$Q=mr\gamma, \quad (4)$$

where *m* is the extractable seam power, m; *r* is a width of the cutter-loader, m; γ is a density of rock mass, t/m$^3$.

Taking into account (3) and (4) it is advisable to use the indicator of energy expenditure of a miner per ton of coal mined

$$\frac{E}{Q}=\frac{E}{vmr\gamma}=\frac{\frac{E_0}{v}+b_1+b_2v}{mr\gamma}. \quad (5)$$

Energy efficiency, in turn, will be determined as

$$CE=\frac{Q}{E}=\frac{vmr\gamma}{E}=\frac{mr\gamma}{\frac{E_0}{v}+b_1+b_2v}. \quad (6)$$

The dependence of the energy efficiency on the feed rate value for different seam power and the width of the cutter-loader is shown in Fig. 4.

The data show that the economy of energy expenditure increases with the growth of both parameters. At the same time, for the feed rate, an extreme value is achieved at the optimum rate.

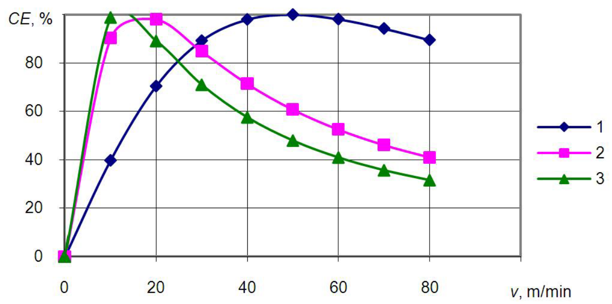


*Fig. 3. Dependence of the economy of a miner on the movement speed along the longwall face:*

*1 – at m > 1.7 m; 2 – at m = 0.81...1.3 m; 3 – at m = = 0.7...0.8 m*

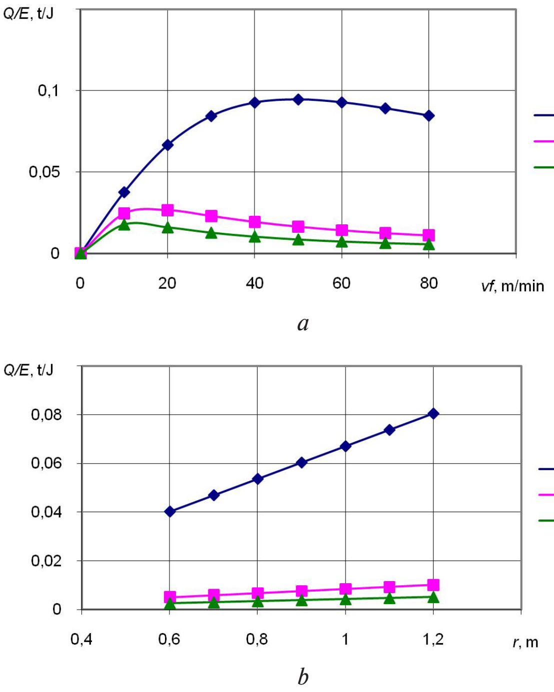


*Fig. 4. Dependence of the economy of energy expenditure on the feed rate (a) and the width (b) of the cutter-loafer:*

*1 – at m > 1.7 m; 2 – at m = 0.81...1.3 m; 3 – at m = = 0.7...0.8 m*

In turn, for a cutter-loader, the power capacity (specific power consumption) for coal mining is determined by the following known methodic

$$H_w = \frac{P_{st}}{60 v_f m r \gamma},$$

where $P_{st}$ is a power (stable) of the cutter-loader engines, kW; $v_f$ is a feed rate of the cutter-loader, m/min; $m$ is a seam power, m; is a width of the cutter-loader, m; $\gamma$ is a density of coal, t/m$^3$.

Thus, with the increase in feed rate of the cutter-loader, the coal mining power capacity decreases, and the power consumption increases. The economy of the cutter-loader during coal mining is inversely proportional to the power capacity

$$H_w^{-1} = \frac{60 v_f m r \gamma}{P_{st}}. \qquad (7)$$

Analysis of formulas (5–7) shows that the power consumption of the cutter-loader during coal mining increases linearly, and the energy expenditure of the miner increases in quadratic dependence with the increase in the feed rate.

The miners and the cutter-loader work as series elements in the coal mining system. If one of the elements fails, the other's work is impossible. In the coal mining system it is necessary to allocate the efficiency of a separate element (machine and person) and the efficiency of the whole system. In the case of sequential operation, the overall efficiency of the system is equal to the composition of the efficiency of its elements $\eta_{tot} = \prod_{i=1}^{n} \eta_i$, with the parallel one – the sum of the efficiency $\eta_{tot} = \sum_{i=1}^{n} \eta_i$. The efficiency of the miner and cutter-loader during coal mining is

$$\eta = \eta_p \eta_m, \qquad (8)$$

where $\eta_p$ is the efficiency of the miner; $\eta_m$ is the cutter-loader efficiency.

Taking into account (6–8) the economy of the mining system (miner and cutter-loader) will be calculated by formula

$$CE_{pm} = \left(\frac{E}{Q}\right)^{-1} H_w^{-1} = \frac{m r \gamma}{\frac{E_0}{v} + b_1 + b_2 v} \times \frac{v_f m r \gamma}{60 P_{st}}.$$

The dependence of the change in the economy of the coal mining system on the width and the feed rate of the cutter-loader is shown in Fig. 5. The dependence of economy on the feed rate is described by the fourth degree polynomial, which is due to the presence of an extremum of the economy function of the machinist on the speed of his movement along the longwall face.

The increase in the economy of the coal mining system is limited due to the physiological capabilities of the miners. Therefore, in order to comply with the rule of economy the energy of a miner it is expedient in coal mining technology to provide the means of mechanized moving of the miner along the longwall face. The economy of the coal mining system increases in the dependence of the quadratic character with the increase in the width of the cutter-loader. To ensure high productivity of coal mining, it is more preferable to vary the width of the cutter-loader.

Thus, the efficiency of the coal mining system is determined by the power consumption of the cutter-loader and the economy of the machinist work, and increases in the dependence of the quadratic character by almost 3 times with a change in the width of the cutter-loader in the range of 0.63–1 m. The efficiency of the coal mining system has a limit determined by the energy expenditure of the miner, while the optimum speed of movement of the miner along the longwall face is as follows: at $m$ = = 0.7– 0.8 m (crawling) it is 12 m/min; at $m$ = 0.8–1.3 m (on the knees) it is 16 m/min; at $m$ > 1.7 m (in normal position – full length) it is 50 m/min.

With the use of the developed methodic of research on the energy expenditure of miners for determining the efficiency of coal mining, full-time experiments were conducted to study energy expenditure during the miners' movement along the longwall face.

Fig. 6 shows the dependence of the change in energy expenditure. Analysis of the graphs shows that the dependence of energy expenditure per unit of distance passed and economy on the speed of movement are quadratic. Dependences of the change in the energy expenditure of miners as they move along the stope are ob-

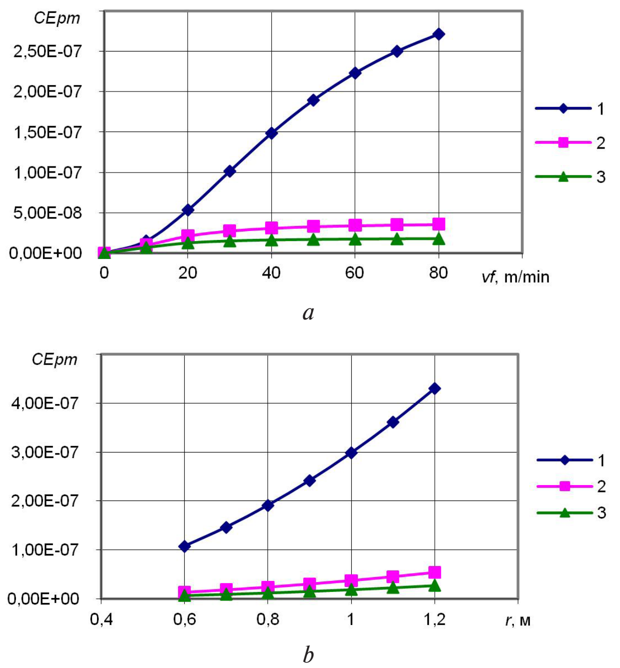


*Fig. 5. Dependence of the economy of mining on the feed rate (a) and the width (b) of the cutter-loader:*

*1 – at m > 1.7 m; 2 – at m = 0.81...1.3 m; 3 – at m = = 0.7...0.8 m*

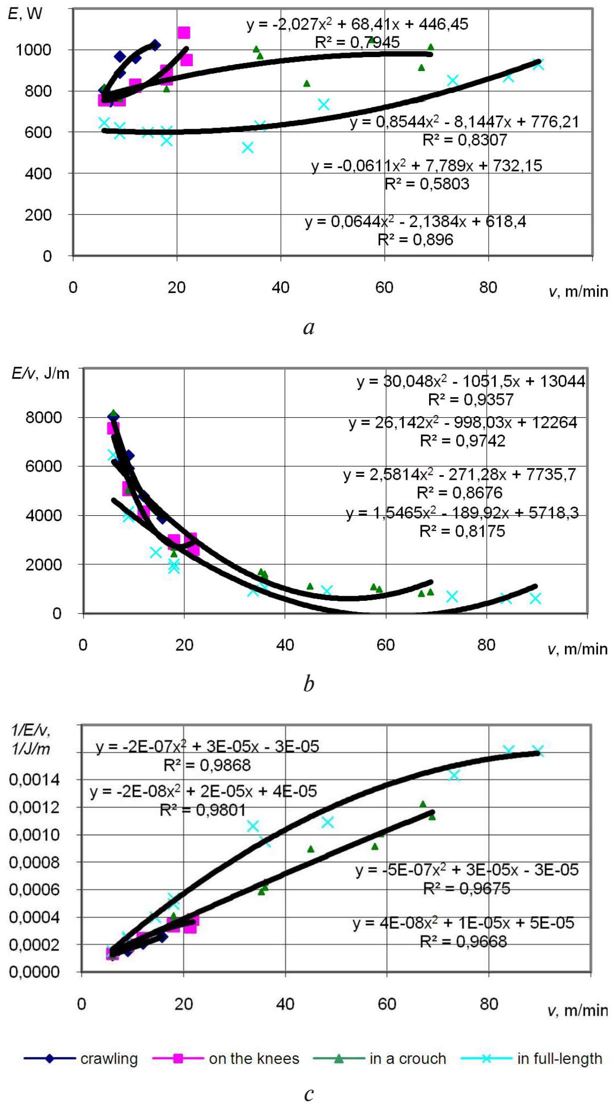


*Fig. 6. The change in energy expenditure due to the speed of movement (a), the energy expenditure per unit of passed distance on the speed of movement (b), the efficiency coefficient on the speed of movement (c) at different positions*

tained. Thus, the dependence of the speed damping in time has a logarithmic character, the change in the current energy expenditure in time, the total energy expenditure on the distance passed, and time has a degree character.

Fig. 7 shows the energy expenditure per unit distance passed on the speed of movement: experimental and calculated by the formula (2). Analysis of the obtained data indicates that the relative error in the average for moving crawling and on all fours was 15 and 20 %, for moving full length the error averaged 30 %, for moving in a crouch – 50 %. The obtained dependences made it possible to refine the (1, 2) for the process of human movement along the longwall face at different positions. The deviation in the data also indicates the significant influence of individual characteristics of a person (total sizes, age, skills, and experience) on energy expenditure when moving. The direction of further research should include obtaining such dependencies on the individual characteristics of miners.

The final stage of the research was to determine the change in the energy expenditure of the miners when performing various operations. During the research, the age, experience, qualifications of the miners varied, as well as such working conditions as dustiness, temperature, and humidity.

The regularities of productivity growth and the level of safety in mines have been established, taking into account the physiological parameters of miners (Fig. 8).

In particular, when miners perform the basic operation in conducting drilling and blasting operations, regularities are established for the change in efficiency with and without the respirator, depending on the age and

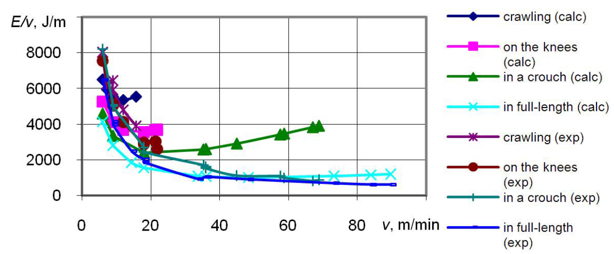


*Fig. 7. Calculated and experimental dependences of the energy expenditure per unit of distance passed on the speed of movement along the longwall face*

skills of workers. It is established that when working with a respirator, productivity in the case of an experienced worker increases by 6 %, and in the case of a young worker, productivity decreases by 15 %. On the basis on the research the methods for determining the energy ex-

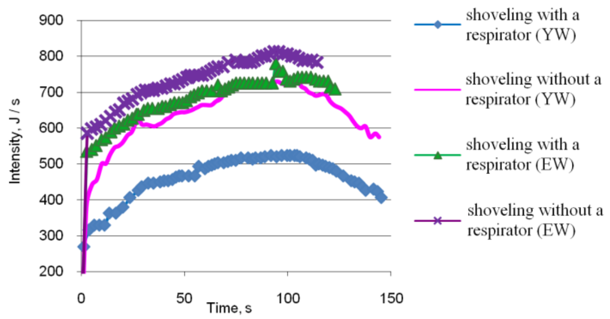


*Fig. 8. Change in the intensity of energy expenditure of miners when rock mass is shoveled by experienced (EW) and young (YW) workers*

penditure and a level of professionalism of miners are developed.

**Conclusions.** The research on the influence of miners' energy expenditure on the productivity of the coal mining system was carried out [9]:

- the total energy expenditure of the machinist increases 5 times when crawling behind the cutter-loader along the longwall face, and the energy expenditure per unit of distance passed decreases by 6 times when moving in the normal position if the feed rate of the cutter-loader along the longwall face increases from 3 to 24 m/min. The quadratic character of the dependence of energy expenditure on the feed rate shows that moving along the longwall face at the constant speed results in less energy than moving at a variable speed;

- the optimal speed of the miner's moving along the longwall face by the criterion of energy expenditure per unit of distance passed while crawling along the longwall face is 12 m/min, on all fours is 16 m/min, in the usual position is 50 m/min. The speed is essentially determined by the seam power, the positions of the miner, the speed and direction of the air movement, the wining scheme, and the individual characteristics of the miner: qualifications, age, physical conditions, etc.;

- it is necessary to use the factor of a miner's energy expenditure per ton of coal mined to estimate the comfort of working conditions. The economy of the miner is inversely proportional to the energy expenditure per ton of coal mined and increases in a quadratic dependence with the increase in the feed rate and increases linearly with increasing width of cutter-loader, varying within the range of 0.007–0.14 t/J with an increase in rate in the range 3–24 m/min and the seam power in the range of 0.8–1.7 m, and in the range of 0.01–0.2 t/J with an increase in the width of cutter-loader from 0.63 to 0.8 m;

- the efficiency of coal mining is determined by the power consumptions of the cutter-loader and the economy of the miner's work, increasing in quadratic dependence by 3 times with a change in the width of cutter-loader from 0.63 to 1 m. The efficiency of the coal mining system is limited by the energy expenditure of the miner, the optimal speed of the machinist's movement along the longwall face: at $m = 0.7–0.8$ m (crawling) is 12 m/min; at $m = 0.8–1.3$ m (on the knees) is 16 m/min; at $m > 1.7$ m (in normal position) is 50 m/min;

- the experimental research made it possible to refine the formula for calculating the energy expenditure per unit of distance passed during the movement of the miner along the longwall face in various positions; it is shown that the achievable maximum speed for a person with average statistical data when moving on crawl and on all fours does not exceed, respectively, 16 and 22 m/min, which is comparable to the design feed rate of modern cutter-loaders. In the near future, the productivity limit of longwall faces will be reached on the biomechanical parameters of the machinist;

- the regularities of productivity growth and the level of labor safety in mines, taking into account the physiological characteristics of miners was established. Thus, when miners perform basic operations while mining, there are established the regularities of change in the coefficient of efficiency when working with and without a respirator, depending on the age and skills of workers. It is established that when working with a respirator, the productivity in the case of an experienced worker increases by 6 %, and in the case of a young worker, productivity decreases by 15 %. Based on the research carried out, methods have been developed for determining the energy expenditure and the level of professionalism of miners.

**References.**

**1.** Jiaqi Ma and Hong Dai, 2017. A methodology to construct warning index system for coal mine safety based on collaborative management. *Safety Science*, 93, pp. 86–95.

**2.** Gerald S. Poplin, Hugh Miller, Joseph Sottile, Chengcheng Hu, John R.M. Hill and Jefferey L. Burgess, 2013. Enhancing severe injury surveillance: The association between severe injury events and fatalities in US coal mines. *Journal of Safety Research*, 44, pp. 31–35.

**3.** Baisheng Nie, Xin Huang, Xin Sun and Anjin Li, 2016. Experimental study on physiological changes of people trapped in coal mine accidents. *Safety Science*, 88, pp. 33–43.

**4.** Hong Chen, Hui Qi, Ruyin Long and Maolong Zhang, 2012. Research on 10-year tendency of China coal mine accidents and the characteristics of human factors. *Safety Science*, 50(4), pp. 745–750.

**5.** Brian V. Shenal, Lewis J. Radonovich Jr., Jing Cheng, Michael Hodgson and Bradley S. Bender, 2012. Discomfort and exertion associated with prolonged wear of respiratory protection in a health care setting. *Journal of Occupational and Environmental Hygiene*, 9(1), pp. 59–64.

**6.** Sheng-Hsiu Huang, Chun-Wan Chen, Yu-Mei Kuo, Chane-Yu Lai, Roy McKay and Chih-Chieh Chen, 2013. Factors affecting filter penetration and quality factor of particulate respirators. *Aerosol and Air Quality Research*, 13, pp. 162–171.

7. Zhipeng Lei, James Yang and Ziqing Zhuang, 2014. Novel algorithm for determining contact area between a respirator and a headform. *Journal of Occupational and Environmental Hygiene*, 11(4), pp. 227–237.

**8.** Golinko, V. I.. Cheberyachko, S. I.. Cheberyachko, Yu. I. and Naumov, N. N., 2014. Comparative research on protective efficiency of filter respirators under laboratory and industrial conditions. *Naukoviy Visnik Natsionalnoho Hirnychoho Universytetu*, 1, pp. 99–105.

**9.** Shevchenko, V. G., 2013. *Scientific and methodological basis for defining readiness of "mining workers - stoping complex" system for increasing coal mining safety*. Kyiv: Naukova dumka.

**Мета.** Встановити закономірності впливу енерговитрат гірників на ефективність видобутку вугілля.

**Методика.** Використані методи математичного моделювання, математичного аналізу, теорії надійності, методи біомеханіки, шахтні, натурні хронометражні та візуальні спостереження з використанням сучасних інформаційних систем, приладів і обчислювальних комплексів.

**Результати.** Встановлені закономірності зміни витрат енергії гірників від швидкості переміщення комбайна в лаві. Встановлена оптимальна швидкість пересування гірника по лаві за критерієм витрат енергії на метр пройденої відстані для різної потужності пласта, що виймається. Для оцінки комфортності умов праці запропоновано використовувати показник витрат енергії гірника на тонну добутого вугілля. Встановлено, що економічність пересування машиніста перебуває у зворотній залежності від витрат енергії на тонну видобутку, зростає лінійно з підвищенням захвата виконавчого органа комбайна та у квадратичній залежності від росту швидкості переміщення комбайна. Ефективність видобутку вугілля визначається економічністю дій гірника й витратами енергії комбайна, зі збільшенням швидкості переміщення комбайна ефективність наближається до обмеження, обумовленого витратами енергії гірників. Встановлені закономірності зміни коефіцієнта корисної дії гірників при роботі з респіратором і без нього залежно від їхнього віку й кваліфікації. При цьому встановлено, що при роботі з респіратором продуктивність у випадку досвідченого робітника збільшується, а у випадку з молодим робітником продуктивність знижується.

**Наукова новизна.** Уперше встановлені закономірності ефективності видобутку вугілля від витрат енергії гірників, швидкості переміщення й ширини захвата виконавчого органа комбайна та визначені обмеження із продуктивності лави.

**Практична значимість.** Розроблена методика досліджень енерговитрат гірників для визначення ефективності видобутку вугілля та професіоналізму гірників шахт.

**Ключові слова:** *гірники, витрати енергії, очисний вибій, ефективність вуглевидобутку*

**Цель.** Установить закономерности влияния энергозатрат горняков на эффективность добычи угля.

**Методика.** Использованы методы математического моделирования, математического анализа, теории надежности, методы биомеханики, шахтные, натурные хронометражные и визуальные наблюдения с использованием современных информационных систем, приборов и вычислительных комплексов.

**Результаты.** Установлены закономерности изменения затрат энергии горняков от скорости перемещения комбайна в лаве. Установлена оптимальная скорость передвижения горняка по лаве по критерию затрат энергии на метр пройденного расстояния для разной вынимаемой мощности пласта. Для оценки комфортности условий труда предложено использовать показатель затрат энергии горняка на тонну добытого угля. Установлено, что экономичность передвижения машиниста находится в обратной зависимости от затрат энергии на тонну добычи, возрастает линейно с повышением захвата исполнительного органа комбайна и в квадратичной зависимости с ростом скорости перемещения комбайна. Эффективность добычи угля определяется экономичностью действий горняка и затратами энергии комбайна, с увеличением скорости перемещения комбайна эффективность приближается к ограничению, определяемому затратами энергии горняков. Установлены закономерности изменения коэффициента полезного действия горняков при работе с респиратором и без него в зависимости от их возраста и квалификации. При этом установлено, что при работе с респиратором производительность в случае опытного рабочего увеличивается, а в случае с молодым рабочим производительность снижается.

**Научная новизна.** Впервые установлены закономерности эффективности добычи угля от затрат энергии горняков, скорости перемещения и ширины захвата исполнительного органа комбайна и определены ограничения по производительности лавы.

**Практическая значимость.** Разработана методика исследований энергозатрат горняков для определения эффективности добычи угля и профессионализма горняков шахт.

**Ключевые слова:** *горняки, затраты энергии, очистной забой, эффективность угледобычи*

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